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EXPERIMENTAL SAFETY VEHICLES PROJECT

NATO Committee on the Challenges of Modern Society

Prepared for:

National Highway Traffic Safety Administration

March 1974

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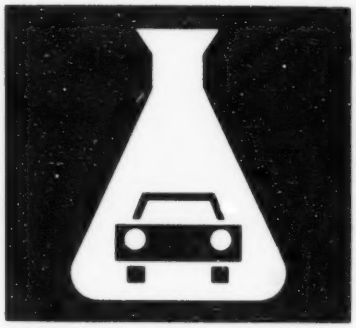

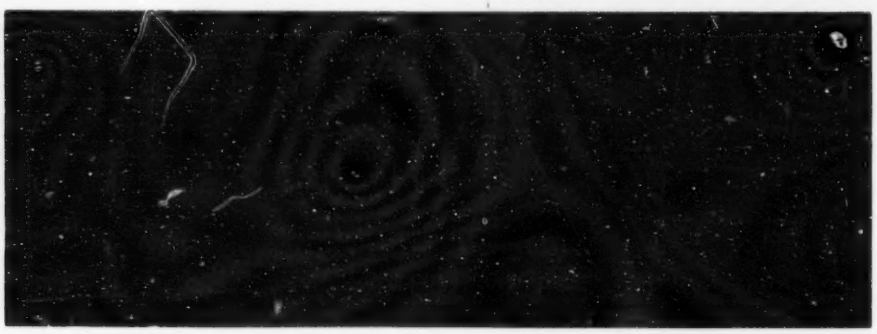

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EXPERIMENTAL SAFETY VEHICLES PROJECT

COMMITTEE ON THE CHALLENGES OF MODERN SOCIETY

CCMS REPORT NO. 23

VÉHICULES EXPÉRIMENTAUX DE SÉCURITÉ

COMITÉ SUR LES DÉFIS DE LA SOCIÉTÉ MODERNE

RAPPORT Nº 23 DU CDSM

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This study has as its purpose to encouragement of governments and industries to undertake costly experimental safety vehicle research and development programs, and exchange the results of these programs with each other. This exchange program was to provide information which would assist governments in developing new motor vehicle safety standards or other techniques for encouraging the development and marketing of substantially safer production vehicles.

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PREFACE

COMMITTEE ON THE CHALLENGES OF MODERN SOCIETY

On April 10, 1969 – less than four months after taking office – President Nixon called for NATO to take action on environmental problems, declaring

> "... (NATO) needs a social dimension, to deal with our concern for the quality of life in this final third of the twentieth century ... the industrial nations share no challenge more urgent than that of bringing 20th century man and his environment to terms with one another ..."

In November 1969, NATO accepted the President's proposal, established the Committee on the Challenges of Modern Society – CCMS – and directed it to improve in every practical way the exchange of views and experience among the allied countries in the task of creating a better environment for their societies, and to consider specific problems with the deliberate objective of stimulating action by member governments.

To carry out its mandate, CCMS has developed a novel approach under which one NATO member as "Pilot" assumes the responsibility to undertake and complete a program. With one-nation leadership, programs move ahead quicker than under the working committee approach which is characteristic of most international efforts. Also, the need for an international secretariat is substantially reduced.

ROAD SAFETY PILOT STUDY

At the first CCMS meeting in late Fall 1969, the U.S. Representative to CCMS proposed all aspects of road safety – vehicle, highway, driver – as a CCMS effort which the U.S. would lead. NATO accepted. The National Highway Traffic Safety Administration of the Department of Transportation conducted the Study for the U.S.

The Road Safety Pilot Study was divided into seven projects, each led by a NATO ally: *Pedestrian Safety* – Belgium; *Alcohol and Highway Safety* – Canada; *Motor Vehicle Inspection* – Federal Republic of Germany; *Identification and Correction of Road Hazards* – France; *Emergency Medical Services* – Italy; *Accident Investigation* – The Netherlands; and *Experimental Safety Vehicle* – United States. Each of these efforts was a self-contained project in its own right and apart from overall coordination by the U.S. as Pilot Country has been directed by the NATO country indicated. The other allies have participated in those projects of major interest to them and such participation is noted in the final report for each of the seven projects. The conclusions and recommendations contained in these project reports are in turn discussed in the overall Pilot Study report.

The basic purpose of CCMS is to stimulate government action – not research per se. While more research is needed in all aspects of road safety, the CCMS premise is that much is already known in one country which other countries might utilize or adapt to their unique problems. Thus, an overriding goal of all of the road safety projects has been to organize the current knowledge on road safety programs of proven effectiveness in a manner that will facilitate putting these programs into practice where they are not now in operation.

EXPERIMENTAL SAFETY VEHICLES (ESV)

The ESV Project under the CCMS Road Safety Pilot Study varies from the central goal of dealing with current knowledge to formulate programs for immediate use in a nation's safety effort. It had as its purpose the encouragement of governments and industries to undertake costly experimental safety vehicle research and development programs, and exchange the results of these programs with each other. This exchange was to provide information which would assist governments in developing new motor vehicle safety standards or other techniques for encouraging the development and marketing of substantially safer production vehicles.

Essentially the exchange of research findings took place at four international conferences held in Paris in January 1971, in Stuttgart in October 1971, in Washington in May 1972, and in Kyoto in March 1973. The reports which have already been distributed on these conferences contain the technical information resulting from the ESV Project.[1]

The following report is a non-technical overview of the history, objectives, accomplishments, and recommendations of the Project.

[1] For availability of these reports see page 10.

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EXPERIMENTAL SAFETY VEHICLES

INTRODUCTION

Automobile manufacturers each year produce increasingly safer vehicles. In the United States, prior to enactment of the safety legislation in 1966, such advances were entirely voluntary on the part of manufacturers. Thereafter, many improvements were still made on a voluntary basis, but most safety improvements could be traced directly to Government-issued safety standards applicable to all vehicles sold in the United States, irrespective of place of manufacture. However, all safety improvements, whether voluntary or mandated, generally were design "add-ons." As late as 1971, no attempt was made to produce a complete vehicle with safety as the dominant design goal.

It became increasingly clear as regulations required vehicles to have more and more safety features that the piecemeal approach was not suitable from the standpoint of producing good design solutions at a price that most people could afford to pay. For without mutually consistent performance requirements or, worse, redundant devices or other requirements not producing much in the way of safety benefits, the price of the car might well be higher than necessary.

The need was for a total systems approach which would both take into account all requirements and desirable goals sought for the vehicle, and assure that all these requirements could be met without violating some overall constraint, such as cost or weight. The systems approach is not new. For example, military and space research and development have long employed the systems approach in designing complex military and space hardware to meet many criteria, not all of which are mutually compatible. However, this approach was not in general use in the automotive safety field, at least with respect to government regulation.

Under the 1966 safety legislation, the United States undertook a program of automotive research and development on a total systems basis. This experimental safety vehicle or ESV program had four objectives:

- To demonstrate the technical feasibility of significant advances in automotive safety performance and crash survival and the environmental effects of such advances through design, development, and testing of experimental motor vehicles.
- To stimulate public awareness of the injury reduction potential and associated economic advantages of advanced automotive safety design.
- To encourage the automotive industry, both foreign and domestic, to increase its level of effort in motor vehicle safety research and to accelerate the integration of advanced safety systems into production vehicles.
- To apply the engineering data from ESV evaluation and testing to development of new motor vehicle safety standards.

However, to begin the process of translating advanced safety concepts into production vehicles, it was apparent that all the major automobile manufacturers should become involved. Automobiles are marketed internationally by only a few highly industrialized nations, but are used throughout the world.

Thus, the ESV Project under the CCMS Road Safety Pilot Study had as its purpose the encouragement of governments and industries to undertake costly experimental safety vehicle research and development programs, and exchange the results of these programs with each other. This exchange program was to provide information which would assist governments in developing new motor vehicle safety standards or other techniques for encouraging the development and marketing of substantially safer production vehicles.

METHOD

As the Pilot Study began, the United States was already heavily engaged in its national ESV program involving the 4,000-pound family sedan which predominates on U.S. roads. This U.S. program accordingly became the foundation for the broader international ESV program under CCMS.

The essence of the CCMS ESV Project was that foreign governments sponsor the development of ESVs in the compact and subcompact vehicle classes to complement U.S. work on the larger 4,000-pound family sedan. All participants agreed to keep each other informed by exchange visits of engineering teams, open discussions at technical meetings, cooperative testing of vehicles, and publication of findings. With these broad purposes in mind, bilateral Memoranda of Understanding were signed between the United States and the Federal Republic of Germany, France, Italy, Japan, Sweden, and the United Kingdom.

Even before these agreements were formally signed, important cooperative exchanges began to take place. With the U.S. ESV program moving rapidly ahead, it was essential to fix upon the

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technical details of the test and performance evaluating procedures that could be applied to the 4,000-pound ESVs. It was thought that the same procedures should be used to test the compact and subcompact ESVs being developed as a part of the CCMS Project. Many useful suggestions from various countries were incorporated in developing a test and performance evaluation system which could be used across the board. More work is required in this respect.

Under the CCMS ESV Project, governments in conjunction with their automotive industries developed comprehensive sets of safety specifications for complete vehicles or as in the case of France and the United Kingdom, worked initially on safety subsystems related to accident data. Then manufacturers undertook or are undertaking the design and construction of prototype vehicles to meet or exceed the levels of safety performance called for in the specifications, either under an award from the government or on a voluntary basis. Details of the design were left to the manufacturers. Some prototypes are still under construction. As construction is completed, the manufacturer delivers the prototype to the government for tests to see whether it meets the defined specifications.

Thus, all ESV work starts with the establishment of the performance specifications which the experimental vehicle must meet. For the purpose of the CCMS Project, the U.S. specifications were the starting point. These specifications emphasized optimum trade-offs between occupant injury reduction, accident avoidance, post-crash factors, and pedestrian safety. The prototype ESV was to demonstrate the upper limits of safety performance of passenger cars using existing state-of-the-art concepts and materials. Highest priority was on "secondary safety," that is the reduction of occupant injuries in crashes. The CCMS ESV Project specifications called for crash survivability with respect to the following equivalent barrier impacts:

- Frontal impacts of 50 mph into a rigid barrier
- Rear impacts at 50 mph
- Side impacts at 30 mph
- Roll-overs at 70 mph

It is useful to note that a frontal impact of 50 mph into a rigid barrier is the approximate equivalent of a normal head-on collision with another vehicle of similar mass involving relative closing speeds of nearly 90 mph. Also included in the specifications for "secondary safety" were the requirements that the vehicle sustain a 10 mph front and rear crash into a barrier without damage and that the problems of fire, pedestrian safety, emergency egress and non-operating safety be addressed. Included in the specifications in the area of "primary safety" were requirements for improved braking, handling and stability, lighting and visibility.

These specifications were developed for a 4,000-pound vehicle, and whether they were appropriate for compact and subcompact ESVs was not known. In fact, a major purpose of the CCMS ESV Project was to identify the maximum levels of safety performance that could be achieved in smaller size vehicles which were both technologically feasible and economically acceptable.

The work under the separate Memoranda of Understanding proceeded. Most of the participating nations have been or are in the process of testing ESVs; others are completing important subsystem developments and other research studies and are now applying the results to production vehicles. Numerous exchange visits of engineering teams were completed, but the most important transfer of technology and exchange of research findings took place in a series of four major international conferences: Paris in January 1971; Stuttgart in October 1971; Washington in May 1972; and Kyoto in March 1973. Complete proceedings of the conferences, including the technical papers presented by the attending government and industry representatives, were published.[2] A fifth conference is planned for London in June 1974.

The last part of an ESV program cycle involves the testing of completed ESV prototype vehicles to determine the extent to which they meet the initially established performance specifications. Extensive tests of the U.S. ESVs, which were the first ESVs to be built, were completed. Observers from all participants in the CCMS ESV Project were present. A prototype Italian ESV built by Fiat was delivered to the United States and tests on it were completed in 1973. In February 1974 Toyota and Nissan FSVs were provided to the United States for testing by a joint Japanese-U.S. engineering team. Negotiations with other countries with respect to ESV exchange testing are now in progress.

The second cycle of ESV activity is now getting started in the United States, drawing heavily upon the findings thus far obtained. Specifically, the United States initiated an Advanced State-of-the-Art Research Safety Vehicle (RSV) Project that takes

[2] For availability of these reports see page 10.

special account of the projected transportation challenges of the 1980's. Safety is still the dominant theme, but the project involves a broader systems approach, addressing such questions as minimizing fuel consumption, urban congestion and pollution, and maximizing resource conservation and safety. The initial proposed specifications for this RSV Project were distributed to all participants in the CCMS ESV Project prior to the Kyoto Conference, and again in June 1973, along with requests for bids to participate in the broad new U.S. program. Contracts for Phase 1 of this program, definition and preliminary design, were signed in January 1974 with AMF, Calspan, Ford, Minicars and Volkswagenwerk.

Discussions are now in progress among the participating nations for other meaningful continued activity. During the Fifth ESV Conference in London, these discussions will center on the possibility of broadening international cooperation to include research areas identified by the initial phase of the ESV Program as requiring additional research effort. Also, during this Conference, participating government representatives will discuss their future ESV plans and programs to continue advancing the state-of-the-art in improved auto safety.

DISCUSSION

Thirteen different experimental safety vehicles already have been built or are under construction, under the various Memoranda of Understanding around which the CCMS ESV program has been developed:

	Weight	Wheel Base
Germany		
Mercedes	4,620 pounds	112.20 inches
Volkswagen	3,200 pounds	110.0 inches
Japan		
Nissan	2,750 pounds	100.4 inches
Toyota	2,530 pounds	90.55 inches
Honda	1,700 pounds	92.5 inches
Italy		
Fiat	1,750 pounds	72.44 inches
Fiat	2,570 pounds	96.4 inches
Fiat	2,840 pounds	95.3 inches
Sweden		
Volvo	3,180 pounds	106.3 inches
United States		
GM	5,080 pounds	124 inches
AMF	6,005 pounds	122 inches
Fairchild	5,440 pounds	121.5 inches
Ford	5,100 pounds	124 inches

(The United Kingdom and France, with their automotive industries, are completing safety subsystems development and will be initiating construction of ESVs in the near future.)

In addition, major subsystems development and testing are expected to produce results to be incorporated into the design and construction of additional ESVs. The United Kingdom has developed subsystems for both "primary and secondary safety" to allow assessment of discrete performance levels and to facilitate cost benefit analysis. Particular attention has been paid by the United Kingdom to pedestrian protection and vehicle compatibility. British Leyland is now developing three complete cars using the results.

It is estimated that governments and industry have thus far invested over $150 million in ESV research and development and the correlated subsystems research. This is an unprecedented expenditure in terms of international cooperative efforts in the field. One may ask what this expenditure is producing by way of results.

The various ESV programs initiated as a part of the CCMS Project are at different stages of development; many of the programs cannot be fully evaluated as yet. Nevertheless, some observations can be made:

The Federal Republic of Germany

Under the leadership of the Federal Ministry of Transportation the German automotive industry has developed ESVs by Daimler-Benz AG and Volkswagenwerk AG. These represent truly impressive engineering work and constitute a significant advancement in safety research applications. The subsystem work by BMW, Opel and Porsche has been of great benefit. The accident investigation evaluations conducted by the Association of Liability, Accident and Automobile Insurers (HUK-Verband) is valuable and will continue to be so as more accident data is compiled and analyzed.[3]

France

Under the leadership of the Institute for Transportation Research, Ministry of Transportation, the French Experimental Safety Subsystems (ESSS)

[3] For a comprehensive technical description, see the Federal Republic of Germany Technical Presentations in Conference Reports listed on page 10.

Program has developed significant accident investigation results through the work done by the Laboratory for Auto Accidents in Lyon. Citroen has completed subsystems work involving the small 1500 pound vehicle which is so prevalent in Europe. The problems of compatibility, large car-small car collisions, has received extensive treatment by Peugeot-Renault. In addition, passive restraint (seatbelt) work has been accomplished by Peugeot-Renault. The French ESSS effort, therefore, has made and is making a substantial contribution to improve vehicle safety.[4]

Italy

The Memorandum of Understanding between the U.S. Department of Transportation and the Italian Ministry of Transport and Civil Aviation was finalized on May 11, 1971. Since that time, the Fiat Motor Company for the Italian Government has developed three experimental safety vehicles in the 1500, 2000, and 2500 pound weight classes. All three of these cars were displayed at the Fourth ESV Conference in Kyoto, Japan. The 1500 pound Fiat ESV was delivered to the U.S. for crash testing which was accomplished in February 1973. The small Fiat showed excellent structural integrity, but there were no provisions made for occupant protection. Negotiations are now in progress for additional ESV exchange. In addition to ESV development, Fiat has initiated a significant road accident analysis effort which now encompasses 40 percent of the total number of cars in circulation in Italy and 50 percent of the accidents recorded. The 2200 accidents have now been analyzed, and some 200 more are examined monthly.

Research on the "compatibility" problem is also in progress. This has involved collision tests of cars of different weights and structural characteristics so as to determine the structural behavior of both production and modified cars.

Finally, Fiat is deeply involved in work to quantify vehicle handling and braking performance to determine the impact of these characteristics on safety.

Alfa Romeo continues its work on active safety (vehicle handling) and improved restraint systems. The Alfa Romeo test car demonstrating advanced operational handling systems has been offered to the U.S. for test purposes and negotiations are now in progress in this respect.

The Experimental Institute of Engines and Vehicles (ISAM) continues its applied research work for the Italian Ministry of Transport. Their work is primarily involved in human factors research.[5]

Japan

The Japanese ESV Program reflects a most serious attack on traffic fatalities and injuries. Supported by the Ministry of Transportation and the Ministry of International Trade and Industry, the Toyota Motor Company, the Nissan Motor Company and the Honda Motor Company are all developing ESVs, final testing of which will be conducted by the Japanese Automobile Research Institute (JARI). A long-term plan has been developed by the Japanese Government for the orderly accomplishment of safety research followed by the development of safety standards. Japan is furnishing the U.S. with Toyota and Nissan ESVs for NHTSA-JARI test purposes.[6]

Sweden

The Swedish Board for Technical Development and the two Swedish car manufacturers, Saab and Volvo, have jointly undertaken a research project on "Steerability during Emergency Braking." This project addresses, among other things, an evaluation of vehicles equipped with anti-skid brake systems in order to propose performance standards and test procedures for steerability during braking. In addition, the Volvo Company has, outside the CCMS ESV Program, developed a most impressive Experimental Safety Vehicle which has received international attention.[7]

The United Kingdom

In May 1971, a Memorandum of Understanding was signed by the U.S. (Department of Transportation) and the United Kingdom (Department of the Environment) under which the two countries undertook to exchange information arising from their respective vehicle safety programs. The United Kingdom safety vehicle program is a collaborative effort between government and industry and is managed by the Department of Environment's

[4] Refer to the French Technical Presentations in Conference Reports listed on page 10.

[5] Refer to the Italian Technical Presentations in Conference Reports listed on page 10.

[6] Refer to the Japanese Technical Presentations in Conference Reports listed on page 10.

[7] Refer to the Swedish Technical Presentations in Conference Reports listed on page 10.

Transport and Road Research Laboratory. Phase 1 of the program consists of subsystems development for both primary and secondary safety to allow assessment of discrete performance levels and to enable cost benefit analysis to be carried out. Work on vehicle structures and occupant protection is being carried out by British Leyland and the Ford Motor Company with supporting primary safety research by these companies and specialist component manufacturers. Particular attention throughout has been paid to pedestrian protection and vehicle compatibility. British Leyland is now developing three complete cars using results from the systems research.

The three vehicles are being designed in a way that will make them close to production vehicles. One of the main purposes of this program is to provide the trade-off data of performance versus weight and cost so as to enable safer cars to become a practical reality. The Laboratory's well-estabiished accident and injury investigation work is continuing to provide background data which has inter alia been used to establish human tolerance levels to impact. The data will thus be helpful in the development of realistic anthropomorphic test devices.[8]

United States[9]

For all practical purposes, each of the four U.S. contractors was able to design vehicles that met the predefined specifications with respect to separate "primary and secondary safety" performance requirements. *However, none of the vehicles was able to meet the overall system specification of 4,000-pound curb weight.* Stated otherwise, the fact that all subsystems performance requirements were met did not in the case of these four vehicles guarantee that the overall system requirement with respect to weight would also be met. This result most graphically illustrates the complete "systems approach" at work. This approach has been the keystone of the CCMS ESV Project. In contrast, more conventional automotive safety research deals only with the safety performance of components and subsystems as separate entities and not in relation to each other.[10]

PROGRESS TOWARD PROGRAM OBJECTIVES

An evaluation of ESV progress in comparison with original U.S. program objectives shows significant accomplishment.

- **Demonstration of the technical feasibility of significant advances in automotive safety performance:** ESV prototypes have been developed and tested; and in the process, it has been shown that most of the specifications can be met or exceeded. The development of a basic structural system and occupant compartment which can protect occupants to the level of the specifications is feasible, but continuing research is needed in the critical areas of anthropomorphic dummy design and human injury tolerance criteria.

- **Stimulating public awareness of the safety and economic advantages of advanced automotive safety design:** Representatives of the news media have attended various important program events. For example, 35 members of the press, worldwide, witnessed the crash testing of one of the Fairchild Industries ESVs; and approximately 60 press representatives attended each of the first four CCMS international ESV conferences. A number of impressive ESVs were displayed at the International Transportation Exposition (TRANSPO 72) held in Washington, D.C., in May-June 1972 and at the CCMS Kyoto Conference in March 1973. In conjunction with displays of low pollution automotive systems being developed as a part of another CCMS program, ESVs were displayed at a CCMS Exhibit at the International Conference of the Society of Automotive Engineers in Detroit in January 1973, and in conjunction with the CCMS Ottawa Plenary in April 1973. The general reaction of the motoring public has been and continues to be favorable, indicating a growing awareness of the potential of advanced automotive safety design.

- **Encouraging the automotive industry to expand its level of effort in safety research and accelerate the integration of advanced safety systems into production vehicles:** As a direct result of the activities the international automobile industry is

[8] Refer to the British Technical Presentation in Conference Reports listed on page 10.

[9] The U.S. Family Sedan ESV Project will be concluded by the issuance of a Final Project Report in calendar year 1974. This report will summarize all ESV work and will include a proposed optimized safety performance specification for a 4500 pound vehicle. In addition, the report will identify research areas which require additional effort. Those research areas are suggested as candidate possibilities for additional international cooperative research. The draft of the final report will be circulated worldwide so that all participants may comment on the substantive issues.

[10] Refer to the U.S. Technical Presentations in Conference Reports listed on page 10.

investing large resources in ESV research. The list of automobile manufacturers participating in this CCMS ESV project encompasses virtually every major manufacturer in the world and dramatically attests to the willingness of the worldwide industry to support ESV development.

The current automotive safety research being conducted by the automotive industry in conjunction with this project not only involves components and subsystems, but addresses the total vehicle as a complete system. This "systems" approach to automotive safety research is the keynote of the CCMS ESV Program and is becoming the foundation for major automotive safety research efforts.

- **Applying the engineering data from ESV evaluation and testing to the development of motor vehicle safety standards:** From the point of the CCMS effort, an important consideration involved the question of the engineering data from ESV evaluation and testing linked to performance requirements for production vehicles. This is part of the broader issue of how all automotive safety research, including ESV research, is utilized to bring about the construction and marketing of safer production cars.

Such research supports development of safety performance standards for production vehicles in two ways:

1. It provides hard and scientifically sound data and test results that relate to a specific regulatory proposal. Such data can be expected to establish (or refute) the technical and economic feasibility of such a proposal. Generally, these research data can be provided within a short time interval, possibly a year or less. The pace of rulemaking substantially depends upon how quickly such needed supporting data can be provided, for without supportive technical information regulations should not be issued.
2. It provides a broad base of data with respect to the optimal total vehicle from the safety point of view. Tradeoffs will be required between competing automotive subsystems, and the total system will have to fit within certain overall constraints, such as those involving maximum weight and cost. The ESV effort is designed to provide this kind of research data and results. The effort does not relate to specific rulemaking proposals, but rather is directed toward vehicle safety problems about which not enough is yet known to contemplate immediate regulatory action. For example, maximum crash protection for a vehicle's occupants, minimum aggressiveness to the occupants of the cars and pedestrians it strikes, and minimum susceptibility to property damage are all important attributes of vehicle design. It is doubtful that maximum performance with respect to one of these attributes can be achieved except at the expense of the others.

Highly complex safety performance problems such as those outlined in the second category above can be systematically studied probably only through the ESV approach. As systems level ESV solutions are developed, more specific subsystem research can be carried out to support additional rulemaking. Thus the ESV programs may be viewed as complementary to the shorter scope subsystem research.

In summary, the ESV work in the CCMS Project demonstrated the technical feasibility of major advances in automotive safety performance through the development and testing of a number of ESV prototypes. Subsystem performance specifications can be met for various "primary and secondary safety" requirements on an individual basis. Although much remains to be learned with respect to better subsystem design, such design does not appear to be the major problem. The truly difficult problem is how to meet different subsystem performance requirements within the boundaries of overall system requirements. This, of course, is *the* "raison d'etre" for the ESV approach.

CONCLUSIONS

Excessive Weight: Without exception, all preliminary and completely tested designs indicate weight increases on the order of 20-30 percent even with the use of high strength steels and some aluminum. Several obvious specification changes have now been identified that could cause a decrease in weight without a serious compromise in crashworthiness, such as rear seat restraints and visibility.

In addition, refinements of initial designs after testing could result in lower weight for some designs, i.e., the AMF and Fairchild ESVs bumpers were over-designed.

Notwithstanding the potential for some weight improvements, it is apparent that the existing ESV specifications, taken as a whole, result in designs of questionable near-term practicality, either because of excessive weight, the need for costly materials or

because the designs require substantial changes in production methods. However, the initial goal of the ESV Program was to establish the possible upper limits of safety performance. This goal has generally been met, and the results of a research experimental program are, of course, not *directly* translatable to production cars.

Aggressiveness: The tendency to improve structural crashworthiness at a cost of increased and unwanted aggressiveness needs to be reversed. The original U.S. ESV specifications included the requirement for lower aggressiveness (car-to-car) at low (10-20 mph) and intermediate (30-60 mph) impact velocities. Several manufacturers developed unique hydraulic stroking mechanisms that demonstrated potential for crashworthiness and low aggressiveness. Other manufacturers sacrificed lower aggressiveness in order to obtain high speed front-end crashworthiness with conventional frame design concepts. Both extremes have demonstrated: (1) good crashworthiness and low aggressiveness in a design of questionable practicality (such as in the AMF and Fairchild designs), and (2) good crashworthiness and high aggressiveness in a more practical but substantially heavier design, such as that developed by General Motors, Ford and possibly Mercedes-Benz.

Volkswagen's initial development approaches the necessary compromise between aggressiveness and crashworthiness but also suffers a marked weight penalty. Other ESV prototypes, such as those fabricated by Toyota, Nissan, Honda, Fiat and Volvo, must await complete testing to determine their structural characteristics.

Operational Handling: It appears that improvements in braking and visibility can be made in most designs at the same time as making marked structural changes to obtain greater crashworthiness. While at the outset of the program, the ability to maintain adequate handling characteristics with major structural changes was seriously questioned, it now appears that good handling can be achieved in such circumstances. The questions now pertain more to "What is the best and most cost effective specification?" rather than the feasibility of providing good performance.

Areas Requiring Research: Certain research areas were identified as requiring additional effort.

- Basic to attenuating impact forces is the need to determine the tolerance limits for the human body in typical traffic accident conditions with and without commercial restraint systems (e.g., seat belts). This area needs further research as it is one of the critical unknowns vital to improved vehicle safety design.
- Better accident investigation data with respect to the frequency and severity of accident types needs to be developed. The cost effectiveness of existing and proposed safety standards requires the preparation of such a statistical base. In addition, it is necessary to develop a valid cost data base, to include not only the initial acquisition costs of proposed new safety performance improvements, but also the operating costs over the life of the vehicle. Cost benefit analysis must, of course, address the elements of the total transportation system, such as, fuel consumption, air pollution, road systems, and driver education.
- The area of accident avoidance, particularly vehicle handling, is difficult to quantify with respect to improved safety performance. Safety performance requirements based only on values derived from current production cars do not have high safety relevance. Requirements must be based on maneuvers that have been proven as critical to accidents with driver involvement.
- Crashworthy vehicle structures for protecting occupants at reasonable costs and without posing additional hazards to other road users need further development. Several different countries have already made original and valuable contributions in this field.
- Efficient restraint systems for vehicle occupants are basic to providing vehicle crashworthiness. No amount of structural effort can be very effective unless it is integrated with occupant protection systems. Promising concepts for such systems are in existence but more development is needed.
- International ESV test procedures are needed. Some participants in the CCMS ESV project are expending large amounts of resources for updating and constructing test facilities, as well as conducting vehicle testing. Although communications with respect to test results have been good, the same cannot be stated of the test methodology employed. It would be beneficial to the overall ESV Program to be able to employ more "common" denominators in the area of testing for the purposes of maximizing data correlation. Improved techniques for both accident avoidance and crash testing should be developed and agreed upon internationally.
- Automobile design which takes into account pedestrian safety is complex. Acceptable solutions

appear to compound design problems and considerably more research is necessary. The Japanese manufacturers have made impressive efforts to attempt to make their ESVs more forgiving of pedestrians; a fact that reflects the large involvement of pedestrians in Japanese road accidents. Several European manufacturers have also addressed pedestrian safety in their designs. As more and more automobiles appear on the world's highways, more attention to pedestrian safety in automotive design is necessary. This requirement must be balanced with the requirement for occupant protection while reducing aggressiveness.

PRINCIPAL CONCLUSIONS

The CCMS ESV Project successfully stimulated an unprecedented investment in cooperative research in automotive safety. An important new body of knowledge has resulted.

In addition, this Project shows that with high-level government support, open and candid exchanges of technical information can be achieved in the highly competitive automotive marketplace of the world, with a concomitant broadening of the participants' perspectives.

Many important aspects of automotive safety have been identified that can be treated effectively with ESV methodology and supportive research. Continued international ESV research and development, using the modalities pioneered in CCMS, can be expected to make further important contributions to automotive safety.

RECOMMENDATIONS

1. That the nations participating in the ESV Program continue the development and testing of Experimental Safety Vehicles, improved safety subsystems and associated research, and continue the exchange of technical information generated as a result of these developments.

2. That the nations participating in the ESV Program establish procedures to allow for cooperative research of those areas identified by the ESV Program as requiring additional efforts.

REPORTS ON INTERNATIONAL CONFERENCES

The First International Technical Conference on Experimental Safety Vehicles, Paris, France; January 25 through 27, 1971. (Available U.S. Government Printing Office, Washington, D.C. 20402 – Stock No. 5003-0036, $1.25)

The Second International Technical Conference on Experimental Safety Vehicles, Sindelfingen, Germany; October 26-29, 1971. (Available U.S. Government Printing Office, Washington, D.C. 20402 – Stock No. TD 8.16:971-2, $2.75)

The Third International Technical Conference on Experimental Safety Vehicles, Washington, D.C.; May 30-June 2, 1972. (Available U.S. Government Printing Office, Washington, D.C. 20402 – Stock No. 5003-0084, $3.00)

The Fourth International Technical Conference on Experimental Safety Vehicles, Kyoto, Japan; March 13-16, 1973. (Available U.S. Government Printing Office, Washington, D.C. 20402 – Stock No. 5003-00143, $7.35)